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(56) Reference Literature
Kokai No. 1985-247515 (JP, A)
Kokai No. 1987-35966 (JP, A)

(57) Claim

1 An optical modeling method characterized by the fact that a light-curable fluid substance that cures by means of light is accommodated within a container, and, while said fluid is being irradiated with light, said irradiated location is caused to move relative to said container in the horizontal and vertical directions in response to the shape of a target model, and in forming a solid body of a desired shape, in order to prevent the deformation of the cured parts in said formation process, the above-mentioned solid body formation is carried out while simultaneously curing and forming a shape maintaining part for attaching to places where there is the danger of deformation occurring in the model, or for reinforcing, extending from said places in the model to other places, and after said formation, the above-mentioned shape maintaining parts are removed as necessary.

Detailed Explanation of the Invention

Industrial Field of Application

The present invention concerns an optical modeling method that forms a solid body of a desired shape using light and a light-curable fluid substance.

Prior Art and Its Problems

Up to now, the manufacture of a model that copes with the product shape regarded as necessary when manufacturing molds, or for the profile control of cutting work and for shape carving electrical discharge machining electrode use, was performed manually or by numerically controlled (NC) cutting using NC milling machines. However, in the case of manual work, there are the problems that much time and skill are required, and when done by NC cutting work, there are the problems of making a complex operation program that takes into consideration the wear and exchangeability due to changes in the shape of

the edge of the blade of an edged tool, and in addition, there are times when further finishing is required in order to remove steps produced on the processed surface.

The inventors propose the optical modeling method shown below as a solution to these kinds of problems (Kokai No. 1985-247515, Kokai No. 1987-101408).

One embodiment of said method is one in which a light-curable fluid substance is accommodated in a container, and the continuous cured part that extends to the top and bottom surfaces of the fluid substance due to light irradiating from above said container is considered the depth that can be obtained, and from the upper part of said fluid substance, via a light converging device such as a convex lens, light irradiating is carried out selectively, and a cured part that extends to the top and bottom surfaces of said fluid substance is formed, and again, on said cured part, a light-curable fluid substance is added so that the depth becomes equivalent to that of the above-mentioned depth on said cured part, and selective light irradiating is carried out from said fluid substance, and a cured part is formed extending to the upper part continuously from the above-mentioned cured part, and these additions of the light-curable fluid substance and the additions of the cured substance and the forming of a cured part are repeated and a solid body of the desired shape is formed.

The addition of the above-mentioned light-curable fluid substance, as shown in FIG. 9, can be carried out by causing the base plate 52 supported by a support pole 51 to descend in said fluid substance A, and, as shown in FIG. 10, the addition can also be carried out by causing a liquid tight box-shaped body with a bottom 61 provided with a bottom wall 62 that has light transmissivity to rise in the fluid substance A. The cured part a shown in FIG. 9 and the cured part b shown in FIG. 10, respectively, are items for which step-like curing is repeated and which are in the process of forming the above-mentioned solid body of a desired shape. In this solid body forming process the occurrence of the various deformations mentioned below become problems.

Generally, the light-curable fluid substance A contracts when curing, and due to the fact that phased curing is repeated, the differences of the amounts of contraction between the cured parts accumulate. Consequently, in the method of adding a fluid substance shown in FIG. 9, there was the problem that deformation occurred due to the difference in the amount of contraction on the edge of said tongue part a' when forming a tongue part a' on the cured part a.

On the other hand, in the method of adding a fluid substance shown in FIG. 10, a body with a bottom 61 is caused to rise for a time from the depth which the above-mentioned continuous cured part has obtained, and the adhesion of the bottom wall 62 to the cured part b is peeled off, and after that the distance between the lower surface of the body with a bottom 61 and the upper surface of the cured part b, is made the distance equivalent to the above-mentioned depth, but there was the problem that the tongue part b' at the time of the above-mentioned peeling caused plastic deformation attendant upon the bottom wall of the body with a bottom 62.

Further, in order to obtain a solid body 41 of a shape like that shown in FIG. 11a in which the bottom surfaces of two truncated square pyramids are each aligned, when solid body formation is carried out, as shown in FIG. 11b, due to the differences in the amounts of contraction, the peripheral side walls become the bending deformed solid body 42, and when the formation of a solid body 43 with the shape of the square roof that projects out shown in FIG. 12a has been carried out, there was the problem that the border of the roof part 44' became the solid body 44 curved upwards as shown in FIG. 12b.

As other embodiments of the above-mentioned optical modeling method, there is the modeling method that causes a container that has taken in a fluid substance A, and a light guide, that leads light emitted from a light source device into the fluid substance A, to move relatively and form a solid body of the desired shape, and a formation method that causes light emitted from two light sources to, respectively, converge in a point, causes the places where the respective light energies are concentrated and irradiated to mutually intersect in a fluid substance A, causes said intersection part to move and forms the

above-mentioned solid body, but in these cases also, there was the problem that the same kind of deformation as that shown in FIG. 9, FIG. 11b and FIG. 12b occurred.

The object of the present invention is to offer an optical modeling method that can prevent the occurrence of deformation when forming the cured part by light irradiation and to solve the above-mentioned problems.

Means of Solving the Problems

The above-mentioned object of the present invention is achieved by an optical modeling method characterized by the fact that a light-curable fluid substance that is cured by means of light is accommodated in a container, and, while light is irradiating into said fluid substance, the relative movement of said place where the light is irradiating is caused, in response to the shape of a target model, in the horizontal and vertical directions, with respect to the above-mentioned container, and in forming a solid body of the desired shape, in order to prevent the deformation of the cured part in said forming process, the above-mentioned solid body formation is carried out while simultaneously curing and forming a shape maintaining part for reinforcement and attaching said shape maintaining part to places where there is the danger of deformation occurring in the model, or extending said shape maintaining part from said place in the model to another place, and, after said formation, removing the above-mentioned shape maintaining part as necessary.

As the above-mentioned light-curable fluid substance, various substances that cure by means of light irradiating can be used, for example, modified polyurethane methacrylate, oligoester acrylate, urethane acrylate, epoxy acrylate, photosensitive polyimide and amino alkyd can be mentioned.

Using a light-curable fluid substance into which a modifying material, such as pigment, ceramic powder and metal powder, has been mixed in advance is also acceptable.

As the above-mentioned light, various lights, such as visible light and ultraviolet light, can be used, depending on the light-curing substance used. Normal light can be used as said light, but by making said light laser light, the advantages can be obtained of raising the energy level and shortening the modeling time, and of utilizing the good light converging ability enabling improvement of the modeling accuracy.

Exemplary Embodiment

Below, exemplary embodiments of the present invention are explained with reference to the attached figures.

FIG. 1 shows a side view of the C-shaped solid body 1 that is the objective. Concerning the modeling method of this solid body 1, FIG. 3, in the method that used a support pole 51 and a base plate 52 (the one shown in FIG. 9), and FIG. 4, in the method that used a box-shaped body with a bottom 61 (the one shown in FIG. 10), each show 1 embodiment when the present invention is applied.

First, the method of the present invention shown in FIG. 3 is explained. First, as mentioned above, the formation of the cured part based on the descent of a base plate 52 into a light-curable fluid substance A and the selective irradiating of a light through a light converging device 6 is repeated and the base part 2 of the solid body 1 is formed on the base plate 52. After the base part 2 is formed, the side wall part 3 is formed extending upwards from one edge of said base part 2, and after that the upper wall part 4 is formed on said side wall part 3, but an appropriate thin tongue part 4' is formed on the lower edge part of the upper wall part 4 by a process that carries out phased curing formation. Said tongue part 4', as shown in FIG. 9, is most easily deformed on the way to the phased curing formation of the solid body 1. Accordingly, when forming a solid body of such a shape, a shape maintaining part 5 for reinforcement is provided extending from the tongue part 4' that is in danger of the occurrence of said deformation to a part in the vicinity of the other edge of the base part 2, and from said supporting part 5 at the same

time as the curing formation of the side wall part 3, and after said side wall part 3 and the shape maintaining part 5 are formed, the upper part 4 that continues on their upper edges is cured and formed. Consequently, in the formation time of the tongue piece 4', the shape maintaining part 5 extending from the base part 2 reinforces and supports the tongue piece 4', and because the occurrence of deformation of said tongue piece 4' is prevented, the upper part 4 can be regarded as not having deformation. By removing the shape maintaining part 5 from a solid body 7 formed in this way (refer to FIG. 2), by a suitable method, such as cutting, a solid body 1 of the desired shape that is not deformed can be obtained.

Furthermore, after the formation of the cured part based on light irradiating has been carried out once, when a fluid substance A is added to said cured part, actually, carrying out the following operation is desirable. As shown in FIG. 7a, when the base plate 52 is caused to descend only the depth the cured part can obtain continued on the cured part, because the distance of the descent of said base plate 52 is extremely small, as shown in FIG. 7b, there are times when said fluid substance A does not flow in onto the cured part, due to the surface tension of the fluid substance A, and reliability is commonly lacking in the above-mentioned addition, furthermore, manual introduction of the fluid substance A onto the cured part is necessary and time is required. In contrast to this, as shown in FIG. 8, if the base plate 52 is lowered more than the above-mentioned depth and the fluid substance A is caused to flow in on the cured part, and, after that the base plate 52 is caused to rise, and the distance between the upper surface of the fluid substance A and the upper surface of the cured part is made a distance equivalent to the above-mentioned depth, the addition of the fluid substance A can be reliably carried out, and the manual introduction of the fluid substance is not required.

Next, the method of the present invention shown in FIG. 4 is explained. Said method, as shown in FIG. 10, is one in which the formation of a cured part, based on the raising in a fluid substance A of a box-shaped body with a bottom 61 and the selective irradiating with a light that passes through the bottom wall 62, is repeated, and a solid body of the desired shape is formed. Said method also, the same as mentioned in FIG. 3, is one in which the base part 2 is formed, and after that, while the curing formation of the side part

3 is being carried out, a shape maintaining part 5 extending to the tongue part 4', which is in danger of deformation, is simultaneously cured and formed from the base part 2, and further, the upper part 4 is formed on said side part 3 and the shape maintaining part 5, and the solid body 7 is obtained with a shape maintaining part shown in FIG. 2, and the shape maintaining part 5 is removed from said solid body 7, and the above-mentioned solid body 1 of the desired shape is obtained without deformation. By means of this method also, the tongue piece 4' which is in danger of being deformed is reinforced and supported by a shape maintaining part 5, accordingly, a solid body 1 of a desired shape can be obtained that is not deformed.

Next, to explain the case of forming the solid body 41 shown in FIG. 11a, in obtaining the external appearance of said solid body 41 based on the optical modeling method shown in FIG. 3 or FIG. 4, while curing and forming the side walls 31, as shown in FIG. 5, if shape maintaining parts 32 for reinforcing are simultaneously formed vertically joining the opposing side walls 31 to each other, the side walls 31 that easily deform in a curved manner mutually support each other via the shape maintaining parts 32, and by means of this, the occurrence of the above-mentioned curved deformation is prevented, and a solid body 33, with the parts 32 that maintain the shape of the correct external appearance attached, can be obtained. Furthermore, in the case of obtaining the solid body 43 of the shape in which a square roof protrudes shown in FIG. 12a, as shown in FIG. 6a and FIG. 6b, first, at the time of the curing and forming of the lower tube body 35, shape maintaining parts 38 for reinforcement are cured and formed that continue to the peripheral part 37', for which there is a danger of deformation, of the roof part 37 from the shape maintaining base part 36 which projects outward from the lower edge of said lower tube body 35 and from the periphery of said base 36, and, shortly, the roof part 37 is formed. By means of this, the peripheral part 37' for which there is a danger of deformation occurring is reinforced and maintained by the shape maintaining parts 38 extending from the shape maintaining base 36, and the occurrence of deformation of the peripheral part 37' as shown in FIG. 12b is prevented, and making the solid body 39 shown in FIG. 6a and FIG. 6b is possible. After said solid body 39 is obtained, by removing the shape maintaining parts 38 and the shape maintaining base 36 from said solid body 39, the solid body 43 of the desired shape can be obtained.

Furthermore, the method of the present invention, as mentioned above, is characterized by the formation of a solid body of a desired shape being carried out while shape maintaining parts for reinforcement that are attached to places where there is the danger of deformation or extending between said places and other places are simultaneously cured and formed, and can be applied to various modeling methods based on light irradiating in so far as this characteristic is provided. Consequently, besides modeling methods based on light irradiating mentioned in the above-mentioned exemplary embodiments, application is possible, for example, in a method that forms a solid body by raising in small increments the upper surface of the light-curable fluid substance in a container and irradiating with a light from above, and a method in which part of the side wall of a container or the bottom wall is a transparent plate, and a base surface is arranged to support the curing part facing said transparent plate, and a solid body is formed on a base surface based on light irradiating through said transparent plate while said base surface is being distanced from the transparent plate. Furthermore, as for the light irradiating in these methods, for example, light irradiating which used a light guide, light irradiating which causes light emitted from multiple light sources to intersect at one point and the irradiating of light in which the large portion of the light intensity in the vertical cross section on the optical axis exhibits a ring shaped light distribution of the quantity of light, can be used. When the above-mentioned light guide is used, if the tip of said light guide is a hemispherical shape, there is the advantage that irradiating can be carried out in which the light is caused to converge so as to concentrate the light energy in a point. Furthermore, if the above-mentioned light irradiating that causes multiple lights to intersect is used, the light energy in said light intersecting place can be caused to increase nonlinearly, and a solid body of a desired shape can be quickly formed. If the irradiating of light with ring shaped distribution of the quantity of light is carried out, with one scan of said irradiating light, a comparatively thick long and narrow solid body can be formed with high dimensional accuracy and the formation of a solid body of a desired shape can be regarded as highly efficient.

Effects of the Invention

As is clear from the above, if based on the method of the present invention, since the place where the energy of the irradiating light is concentrated is caused to move relative to a light-curable fluid substance in forming a solid body of a desired shape, in said formation process, the above-mentioned solid body formation is carried out while shape maintaining parts for reinforcement attached to places where there is the danger of deformation occurring in a model, and extending from said places to other places in a model are simultaneously cured and formed, and after said formation the above-mentioned supporting parts are removed when necessary, based on said shape maintaining part, an optical modeling method can be offered that reliably prevents the occurrence of the characteristic deformation when forming a cured part by means of light irradiation.

Brief Explanation of Drawings

Figure 1 is an oblique view that shows an example of the solid body that is formed based on the method of the present invention; Figure 2 is an oblique view that shows an example of the solid body with the shape maintaining part attached; Figure 3 is a diagram that shows, in summary form, an exemplary embodiment of the method of the present invention; Figure 4 is a diagram that shows, in summary form, another exemplary embodiment of the method of the present invention; Figure 5 is an oblique view that shows the solid body with the shape maintaining part attached obtained based on the method of the present invention; Figure 6a is an oblique view that shows a solid body with the shape maintaining base and the shape maintaining parts obtained based on the method of the present invention attached; Figure 6b shows its vertical section front elevation; Figures 7a and b are diagrams that show the situations of adding the conventional light-curable fluid substance which use a support pole and base plate; Figure 8 is a diagram that shows the method that can reliably add said fluid substance; Figure 9 is a diagram that shows, in summary form, an example of the conventional optical

modeling method; Figure 10 is a diagram that shows, in summary form, another example of the conventional optical modeling method; Figure 11a is an oblique view that shows a solid body regarded as what should be obtained based on the conventional method; Figure 11b is an oblique view that shows a solid body formed based on the conventional method; Figure 12a is an oblique view that shows another solid body regarded as what should be obtained based on the conventional method; Figure 12b is a vertical section side view that shows a solid body formed based on the conventional method.

1 Solid body of desired shape
4' upper piece bottom part (tongue part)
5, 32, 38 Shape maintaining part
6 Light converging device
A light-curable fluid substance

Figure 1
Figure 2
Figure 3
Figure 4
Figure 5
Figure 6a
Figure 6b
Figure 7a
Figure 7b
Figure 8
Figure 9
Figure 10
Figure 11a
Figure 11b
Figure 12a
Figure 12b